PHYSICS 1020

Homework set 4

22 January 1997

[**4.6**] If you exert a force on an object and then exert three times as strong a force on the same object, what (if anything) can you say about the object's acceleration during the exertion of each force?
Answer:
Since the acceleration is proportional to the force, the acceleration would be three times as large for the three times bigger force.

[**4.7**] A ball weighing 8 newtons is thrown straight upward. Disregarding air resistance, find the direction and strength of the net force on the ball as it moves upward. What is the direction of the ball's acceleration? Are the net force and the acceleration in the same direction in this case? Can they ever be in different directions?
Answer:
If there is no air resistance, the weight is the only force acting on the ball; therefore the net force is the weight. Its strength is 8 newtons, and it is directed straight down, as is the acceleration – th ascent of the ball is slowing down. Both acceleration and force are vectors, and the acceleration vector due to a force is proportional to the force vector; an acceleration is always in the same direction as the force causing it.

[**4.11**] A car weighing 8000 newtons moves along a straight level road at a steady 80 km/hr. The total resistive force on the car is 500 newtons. Find the net force on the car, the acceleration of the car, and the drive force.
Answer:
Since the car is in uniform motion (at constant speed in a straight line), it is not accelerated, and the net force must be zero. The weight of the car is balanced by the contact force exerted by the road on the car, and the resistive force on the car is balanced by the drive force.

[**4.12**] The car of exercise 11 has a mass of 800 kg. The driver pushes down on the accelerator, increasing the drive force to 2100 newtons. All other forces on the car remain unchanged. Find the net force on the car, the acceleration on the car, and the direction of both.
Answer:
Now the drive force is bigger than the resistive force, and the net force on the car = (2100 - 500) newtons = 1600 N in the forward direction. The acceleration is therefore also in the forward direction; the value of its magnitude can be calculated from Newton's second law of motion:

$$a = \frac{F}{m} = \frac{1600\ \text{N}}{800\ \text{kg}} = 2\ \text{m/s}^2$$

[4.13] The driver of the car of exercises 11 and 12 lets up on the accelerator, reducing the drive force to only 100 newtons. All other forces remain unchanged. Find the net force on the car, the acceleration of the car, and the direction of both.
Answer:
Now the drive force is smaller than the resistive force, and therefore there is a net force in the backward direction. Its magnitude is = (500 - 100) N = 400 N. The acceleration is

$$a = \frac{400 \text{ N}}{800 \text{ kg}} = 0.5 \text{ m/s}^2$$

The direction of both net force and acceleration is in the backward direction – the car is slowing down.

[4.14] A freely falling apple has a weight of 1 N. Earth's mass is 6×10^{24} kg. How strong is the force exerted by Earth on the apple? How strong a force does the apple exert on Earth? How big is the apple's acceleration? Find the acceleration that the apple would cause the Earth to have if the apple were the only object exerting a force on Earth.
Answer:
The force of Earth on the apple is = its weight = 1 N downwards. According to Newton's 3rd law (the law of action/reaction pairs), the force exerted by the apple on the Earth is equal in magnitude and opposite in direction, so it is = 1 N upward (toward the apple). The magnitude of the Earth's acceleration due to this force is

$$a = \frac{F}{m} = \frac{1 \text{ N}}{6 \times 10^{24} \text{ kg}} = 1.7 \times 10^{-25} \text{ m/s}^2.$$

This is too small to be measured.

[4.22] "Planet Earth is pulled upward by a boulder with just as much force as the boulder is pulled downward toward Earth." True or false? Why?
Answer:
This statement is true; it follows from the law of action/reaction pairs.

[4.23] "Planet Earth is pulled toward a falling boulder with just as much acceleration as the boulder has as it moves toward Earth." True or false?
Answer:
This statement is false; the force exerted by the boulder on Earth has the same magnitude as the force exerted by the Earth on the boulder, but due to the difference in mass, the accelerations are very different. The boulder has a much larger acceleration than Earth.

[4.25] A car collides head-on with a large truck. Which vehicle exerts the stronger force? Which has the larger force exerted on? Which experiences the larger acceleration?
Answer:
The vehicles exert forces of the same magnitude on each other, and they feel equally strong forces from the other vehicle. Due to its smaller mass, the car experiences a larger acceleration than the truck.

[4.26] When a rifle recoils, it accelerates a bullet along the barrel. Explain why the rifle must recoil.
Answer:
In order to accelerate the bullet, the rifle must exert a force on it; by the law of action/reaction (Newton's 3rd law), the bullet must exert a force on the rifle equal in magnitude and opposite in direction.
Another way to look at the same situation is by invoking momentum conservation: before the shot, the total momentum of the system consisting of rifle and bullet is zero (assuming the rifle was at rest). After the shot, the bullet is flying away at high speed, thus it has momentum = mass of bullet $\bullet$ speed of bullet = mv. Since momentum is conserved, the total momentum of the rifle-bullet system must still be zero; therefore the rifle must have a momentum equal to that of the bullet, but opposite in direction.

[4.27] A 2-newton apple hangs by a string from the ceiling. Describe the two forces on the apple. How strong is each of these forces? Do these forces form a single force pair (i.e action-reaction pair)? If not, then, for each force, describe the other member of that force's action-reaction pair.
Answer:
The forces felt by the apple are the upward force exerted on it by the string (string tension) and its weight, i.e. the downward force from the Earth's gravity. These two forces are not an action/reaction force pair in the sense of the 3rd law. The partner of the string force is the downward force exerted by the apple on the string (due to its weight), and the partner of the apple's weight is the upward force exerted by the apple on the Earth.